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The Silt-Free Reservoir
A More Reliable Impoundment for Providing Drinking Water to Livestock and Wildlife

Technical Note 388

U.S. Department of the Interior
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The Silt-Free Reservoir
A More Reliable Impoundment for Providing Drinking Water to Livestock and Wildlife

by

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U.S. Department of the Interior
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Introduction

When storing drinking water in reservoirs for grazing animals (livestock and wildlife), dependability of the facility is critical. Often, however, when the water is needed most, the reservoir is dry. According to Stoddart and Smith (1955), "Its disadvantage lies in the fact that it depends upon surface runoff or seepage and may be empty when most needed, as in the time of drought or in dry seasons of the year."[1]

Recognizing the above statement as being accurate, the author of this paper does not recommend reservoirs as a source of water over springs and wells, which are consistently more reliable. However, on lands inhabited by grazing animals where springs and wells are absent, a reservoir can still be a viable source of water if properly located, designed, and constructed.

During the past 12 years, the Richfield District has developed a water impoundment referred to as the "Silt-Free Reservoir" (SFR). It is designed to store water more efficiently for a longer period of time, and it has a service life two to three times that of a typical reservoir.

An SFR consists of two basins. As surface water enters the impoundment area, it is first detained in a flat-bottomed basin (silt trap and secondary basin), where it drops the majority of its silt. It is then conveyed by an inlet pipe through a dike into the main storage basin, which is specifically designed to store the water efficiently. If runoff exceeds the capability of the inlet pipe to handle the water to the extent that the secondary basin becomes full, then excess water exits directly via the spillway. This provides a bypass and protection to the main storage basin. (See drawing for details.)

There are five primary features and advantages of an SFR:

1. The structure is relatively maintenance-free when located, designed, and constructed properly.

2. The SFR's water supply lasts longer than it does in the typical reservoir. (The typical reservoir referred to in this text would consist of an earthen impoundment across a drainage channel, with a storage basin perhaps similar to the oval-shaped one illustrated in Figure 2.)

3. An estimated 90 percent of the sediment is dropped in the silt trap and secondary basin outside the main water storage basin. Thus, when removal of silt is necessary, it can be done more efficiently.

4. Bentonite or an artificial liner, if needed, can be applied to the main storage basin using a minimal amount of material.

5. In addition to providing drinking water for grazing animals, an SFR also provides a more reliable source for waterfowl, upland game, and aquatic species.

The narrative in the following section of this document will concentrate on the second feature noted above, which is related to the capability of the structure to minimize water loss. The other features, which are also vitally important, are illustrated in Figures 4 and 5 and are covered in less detail later in the text.

SFR Mechanics and Costs

In designing a reservoir, it is important to analyze the factors that contribute to water loss after the water has reached the impoundment.

Factors affecting water loss include:

A. Consumptive

1. Livestock
2. Wildlife
3. Living plants

B. Nonconsumptive

1. Infiltration (seepage into soil)
2. Evaporation

Generally, most of the water loss in a reservoir can be attributed to nonconsumptive use, usually between 70 and 85 percent; consumptive use is generally less than 30 percent. For example, normal demand at any one water source on the open range can be as high as 75 animal units (1 animal unit equals 1 cow or 5.8 mule deer) for 5 months. Assuming that each animal unit consumes an average of 15 gallons per day from an impoundment containing 2 acre feet (651,658 gallons), total consumption would be 171,563 gallons, or approximately 26 percent of total volume. This calculation is based on the assumption that, with no additional recharge, the impoundment would be dry at the beginning of the next grazing season; the remaining volume of water would be lost to infiltration/evaporation.

The consumptive use of water in a reservoir by living plants is considered insignificant and will not be discussed further in this document.

Figure 1 illustrates the sources of nonconsumptive loss around a body of water.

Stoddart and Smith (1955) have noted that "important considerations in reservoir construction are the losses from evaporation and underground seepage."[1] The key, then, to an effective storage facility is to reduce the contact zones of water-to-air and water-to-soil to minimize evaporation and seepage.

Figure 1.

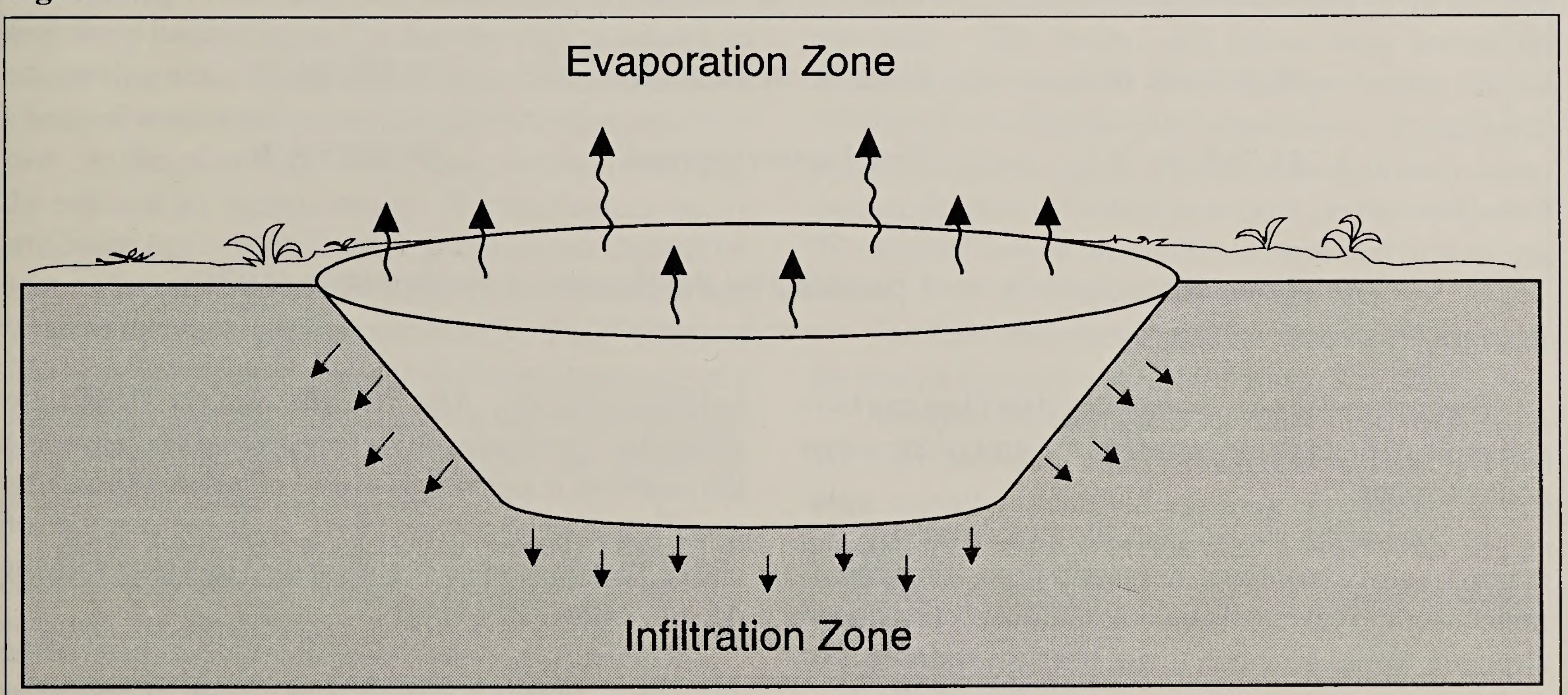
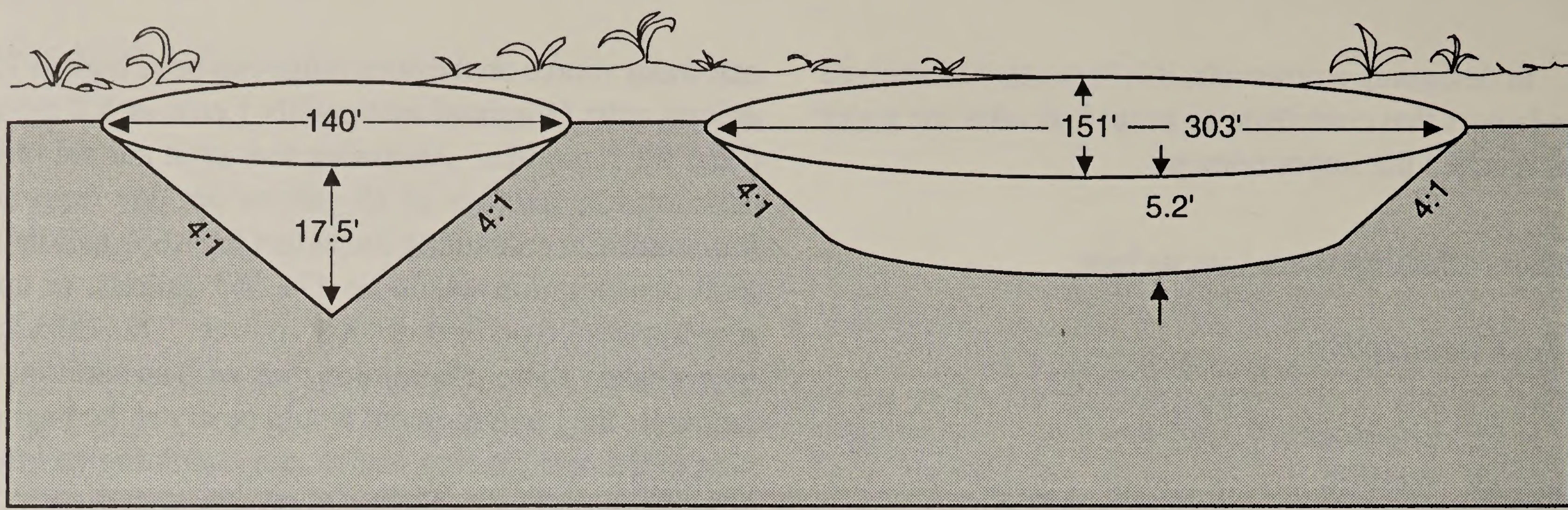


Figure 2.



Cone-shaped		Oval-shaped
2.06 ac. ft.	Volume	2.06 ac. ft.
4 : 1	Side slopes	4 : 1
140 ft.	Diameter	151 X 303 ft.
440 ft.	Perimeter	777 ft.
17.5 ft.	Depth	5.2 ft.
15,394 sq. ft.	Water-to-air contact	22,971 sq. ft.
16,321 sq. ft.	Water-to-soil contact	35,625 sq. ft.
31,715 sq. ft.	Total water contact	58,596 sq. ft.

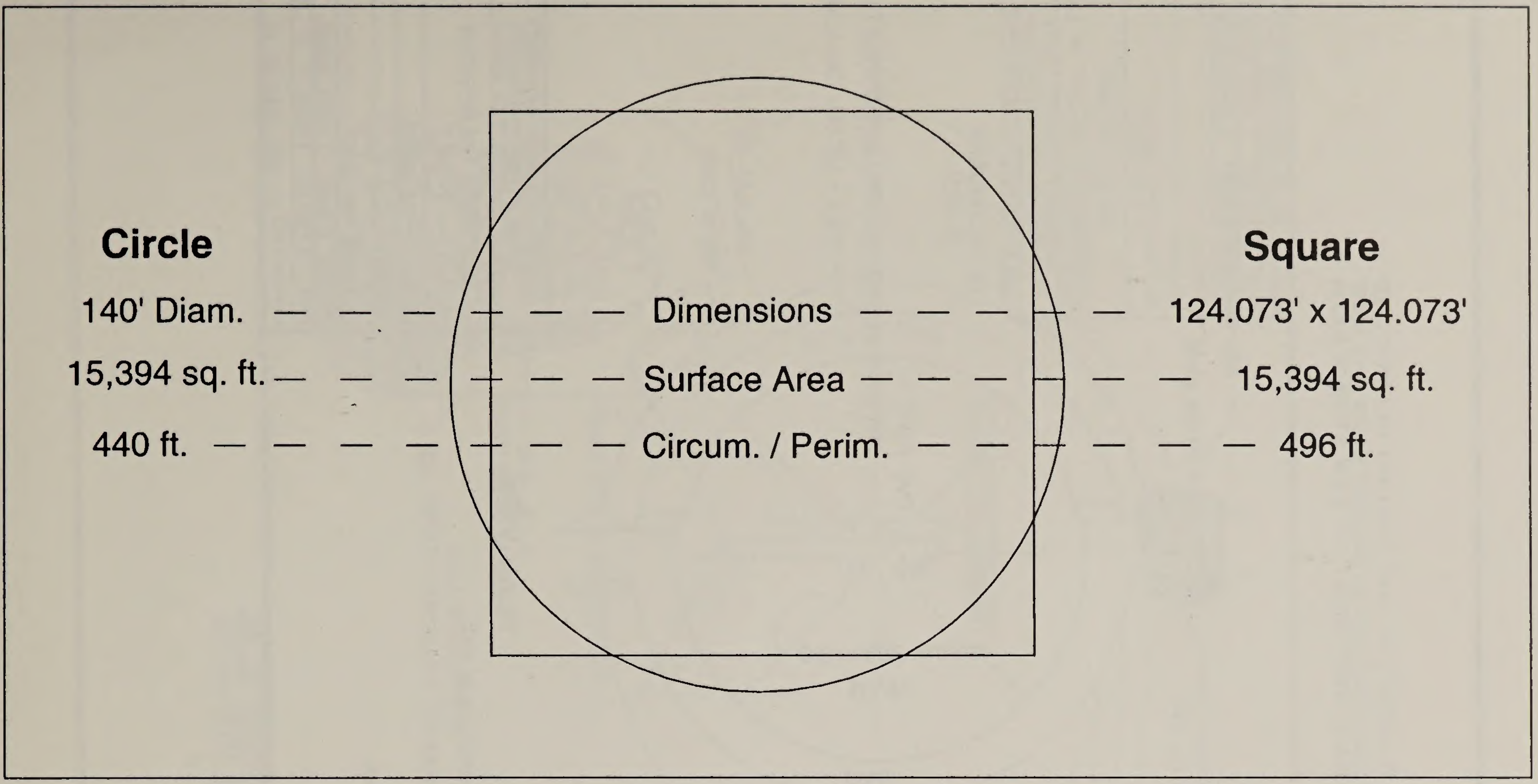
The above computations were provided by the Bureau of Reclamation (1991).[2]

Figure 2 and the accompanying data illustrate how reservoir size and shape can affect the area of these two contact zones.

In comparing statistics of the two structures described above, assuming site conditions are similar, nonconsumptive water loss in the circular-cone-shaped structure would be much lower because water-to-soil and water-to-air contact zones are substantially less. This is true even though both have the same water holding capacity. The Wildlife Society (1969) has noted that "reducing the surface area while deepening the reservoir is a principal means of reducing evaporation."[3] It is quite obvious then, from the comparison above, that this can be accomplished by going with the deeper, cone-shaped unit.

It is also important to minimize the perimeter of the shoreline. Figure 3 gives a comparison of perimeter lengths between circular and square structures.

Figure 3.



It is interesting to note that while both the square and circular figures cover the same amount of surface area, the circular one has a perimeter or shoreline that is 11 percent shorter. A rectangular or oval shoreline covering the same surface area is even more out of proportion, as illustrated in Figure 2.

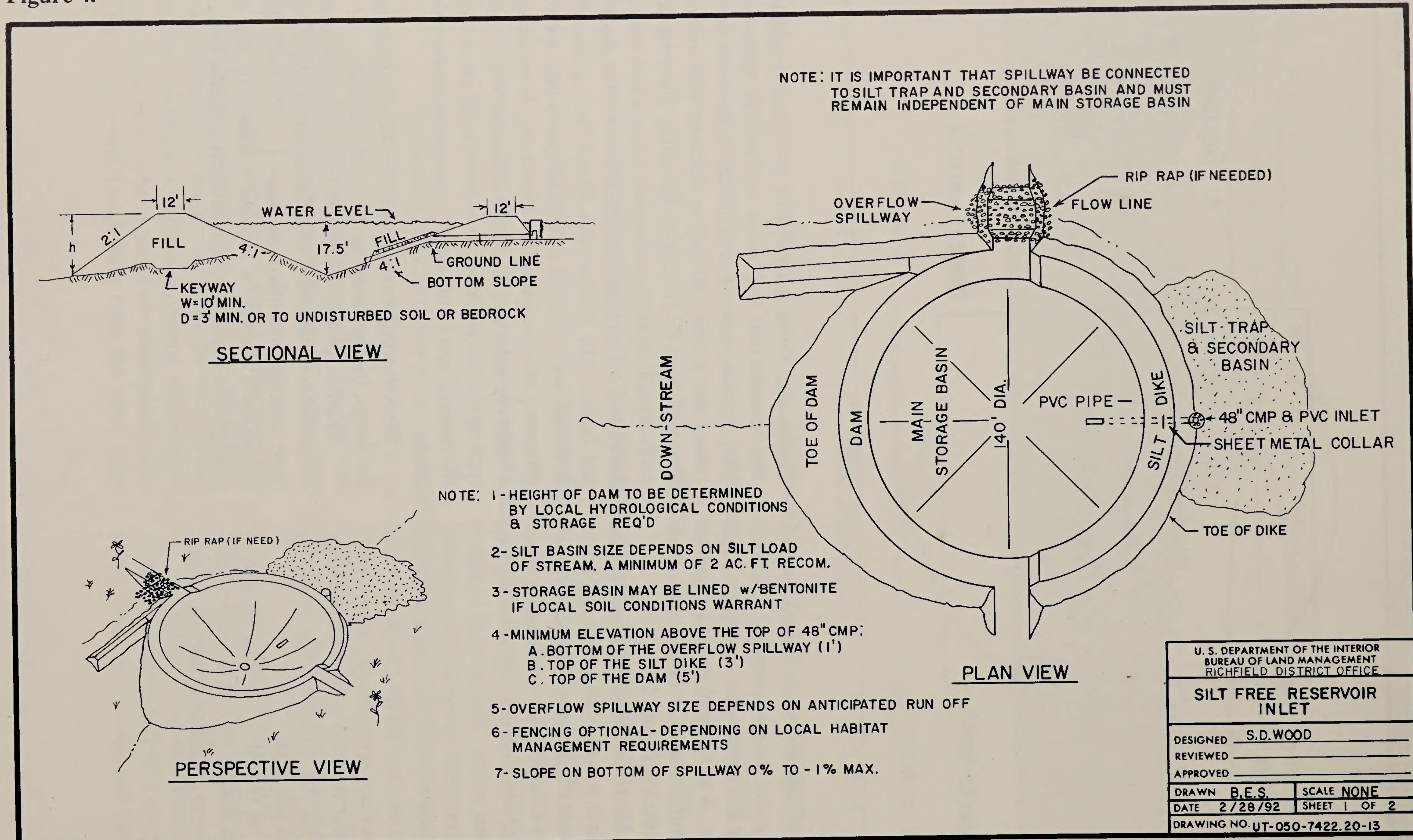
Although this 11 percent difference in perimeter may seem insignificant, it in fact has a great impact on conserving water lost to evaporation. The shoreline of a body of water yields a much higher loss than any other part. At this point, the water comes in touch with both the soil and air contact zones. The increase in rate is attributed to (1) higher water temperatures caused by heat radiating from the warmer inundated soils just beneath the water surface and (2) the "wick" affect of thin layers of water in wave action being intermittently dispersed over even warmer soils at the shoreline edge. Thus, when designing the shoreline, the perimeter should be as round as possible.

Since inception of the SFR, various designs of circular-cone-shaped storage basins have been constructed, using different diameters, bottom slopes, depths, etc. From analyses that have been conducted and consultations with range and wildlife specialists from various resource area offices, it has been determined that a unit 140-feet in diameter with bottom slopes of about 4:1 is the most desirable. This structure will normally store approximately 2.0 acre feet, with an additional 2-3 acre feet capacity or more in the secondary basin. The design also allows easy access for livestock and wildlife, while still providing for the efficiency of a circular-cone-shaped unit. Even though a larger diameter unit may seem more desirable, dozer-type equipment is limited as to how far the excavated/ fill material can be efficiently transported to form the dikes.

The following drawings (Figures 4 and 5) illustrate the design that seems to be the most desirable.

Based on the above data and drawings, we are now in a position to elaborate on the features of the SFR that were initially identified on page 1. (Refer to the photographs shown in Figures 6 and 7 to see an example of an actual SFR constructed on public lands.)

Figure 4.



STANDARD DRAWING SHEET (10½" × 18") Form 9100–7a (March 1980)

Figure 5.

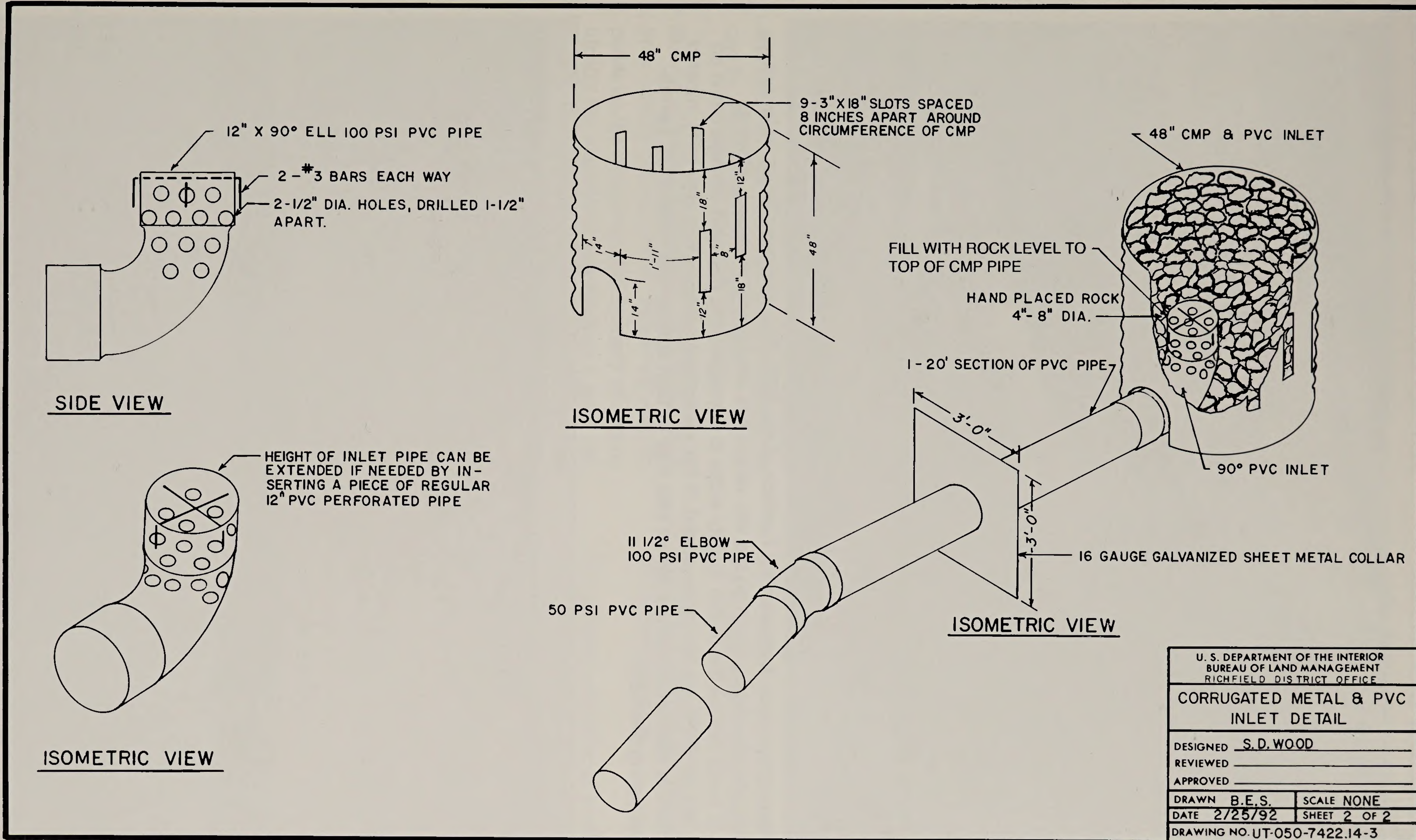


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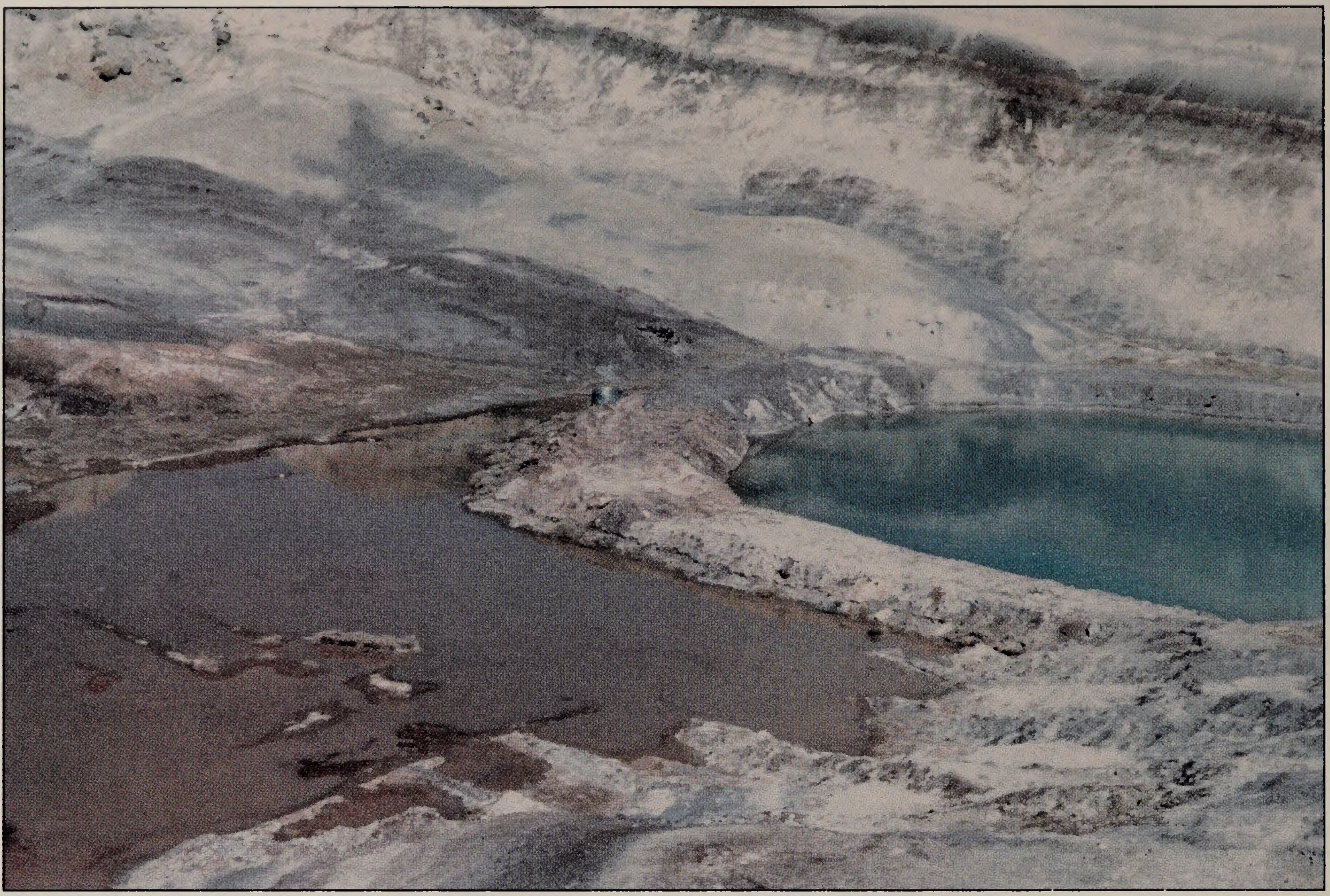
Figure 6.



This photo perhaps best illustrates the function of the SFR. The sediment-laden water enters the silt trap and secondary basin on the left, where it is temporarily detained, allowing desilting to occur before the higher quality water is conveyed into the main storage basin on the right. Not all SFRs are this pronounced. If the watershed contains fine clay soils, most of the sediment is retained but some lighter silts may remain suspended indefinitely, permanently discoloring the water.

Figure 7.

Deep, circular cone-shaped structures such as this one, where natural soils are tightly sealed, will seldom go dry.

1. The structure is relatively maintenance-free when located, designed, and constructed properly.

   In planning for an SFR in the Richfield District, we go through an evaluation process that we refer to as the six S's for perfecting a reservoir:

   - Site. A reservoir should be located on a relatively flat gradient so that the back-up effect of water in the storage area behind the earthen dam can be maximized. In addition to the main storage basin, it is vitally important to provide a large area for the silt trap and secondary basin; 2 to 3 acres or more for the latter is desirable. Natural terrain should be utilized where possible to complement storage. The site can either be on or off channel, depending on the character of the channel and also on the surrounding area. Impervious clay soils are preferable to sandy, gravelly, or rocky soils.

     Older existing reservoirs that are partially full of sediment, but yet still have a sound earthen dike and spillway, often provide an excellent site that can be readily converted to an SFR.

   - Source of water (watershed). This factor needs very careful consideration. Reservoir size depends on the frequency and intensity of storms. Ideally the watershed will produce a good volume of low-sediment-laden water two or three times annually. Gentle runoff generated by melting snow is ideal; an expansive area of sandstone or other rock surface draining toward a common channel is excellent.

   - Spillway. This is very critical factor that is often neglected. The primary cause of mechanical failure of most reservoirs is an unstable spillway. First, spillways should be large enough to accommodate a 25-to 50-year storm. If natural rock is not available, a wide spill on a 0 to 0.5 percent grade perhaps several hundred feet long may be appropriate. If headcutting is still a threat, then rip-rapping should seriously be considered.

   - Storage. The volume of storage should be sufficient to endure prolonged periods of drought when no surface runoff occurs. However, even more important than volume is the shape of the storage area. It needs to be properly designed to store the water as efficiently as possible. Refer to the previous section of SFR Mechanics or see item 2 below for more detailed information.

   - Sealant. Will bentonite or an artificial liner be needed to check infiltration? Sandy and/or gravelly soils are high yielders to water loss and, if not adequately sealed, can result in an extremely unreliable source of water. However, even with course soils, sealing can be accomplished naturally in due time if the watershed contains some fine clay material.

   - Sedimentation. This is generally a serious problem, especially in arid desert areas where sparse vegetation contributes to an unstable watershed and where surface runoff is frequently generated by flash-flooding conditions. Accumulation of sediment adversely affects a structure in two ways. First, storage capacity is lost as sediment accumulates and second, the shape of the storage area is changed, thus increasing the water-to-air and water-to-soil contact zones. It is important to provide for sediment and yet keep as much of it as possible out of the main water storage basin.

2. The SFR's water supply lasts longer than it does in the typical reservoir.

   The primary objective of a reservoir as discussed in this document is to provide adequate water for consumptive use of grazing animals. Thus, when designing an impoundment, it is important to design the structure so that nonconsumptive losses are minimized. This is done by constructing a unit that is deep, circular, and cone-shaped, thereby reducing the water contact zones that contribute to evaporation and infiltration.

3. An estimated 90 percent of the sediment is dropped in the silt trap and secondary basin outside the main water storage basin. Thus, when removal of silt is necessary, it can be done more efficiently.

   The secondary basin is flatter and the sediment stored here will be dry much of the time due to the demand for water in the main basin. Therefore, it will be much more efficient to remove the drier sediments from this flatter basin than from the bottom of a typical reservoir basin, where the sediments would be wetter and more difficult to work with.

4. Bentonite or an artificial liner, if needed, can be applied to the main storage basin using a minimal amount of material.

   Again, the key here is to minimize the area of the soil-to-water contact zone first as specified for an SFR. Then, if a soil sealant is needed, the only part that would require treatment would be the main storage basin. A typical non-SFR reservoir would be broader, flatter, and more spread out and would therefore require a greater volume of material to stop the infiltration problem. (This principle is illustrated in Figure 2.)

5. In addition to providing drinking water for grazing animals, an SFR also provides a more reliable water source for waterfowl, upland game, and aquatic species.

   Our experience with SFRs over the past several years has shown that, given the presence of a reliable source of water, waterfowl are generally present on each pond. Tracks of upland game and other wildlife species are frequently observed. In addition, the wetland values are enhanced by germination and growth of ephemeral grass, shrubs, and trees.

Cost:

Based on current contract prices, the estimated cost would be:

- **Equipment**
  - D-6 Dozer or equivalent with hydraulic ripper and operator - 65 hrs* @ $75 .... $ 4,875
- **Materials**
  - CMP pipe, 4' x 4' 85
  - PVC 80 psi 90° el 90
    12" diameter
  - PVC 50 psi, 12" diameter
    60 ft. @ $3.50 210
- **Labor**
  - Cutting slots in CMP, perforating 90° el, installation of pipes and rock work - 16 hrs. @ $15.00 240

Total Cost .... $ 5,500

*This figure is based on ideal soil conditions. Subsurface rock and/or lack of fill material would increase the hours accordingly.

The cost of a silt-free structure is higher than the typical reservoir in the same size class by about $2,100. This includes 20 additional hours of equipment-operating time required in constructing the silt-free dike between the water storage pit and the silt storage area, plus the cost for materials and labor for the inlet structure.

Summary

During the past 12 years, the silt-free reservoir has undergone continual development at the Richfield District. It is designed to store water more efficiently for a longer period of time, and an SFR has a significant service life beyond that of the typical reservoir.

This is accomplished by slowing down silt-laden surface water as it enters the reservoir site, causing it to drop about 90 percent of its silt before entering a circular-cone-shaped storage basin, where the water-to-soil and water-to-air contact zones have been minimized to reduce nonconsumptive water losses.

In addition to providing a more reliable source of drinking water for grazing animals, this facility expands the habitat of nongrazing animals as well, including waterfowl, upland game, and other aquatic wildlife. Riparian or wetland values become stabilized by the availability of a more consistent source of impounded water.

The initial cost for the structure is an estimated $2,100 higher than a typical reservoir of the same size. However, if properly located, designed, and constructed, the service life of the silt-free reservoir may be as long as 20 to 25 years with minimal maintenance and could be expected to outlast a typical unit by two to three times.

References

1. Stoddart, L. A., and A. D. Smith, 1955. Range Management, (second edition), p. 401. McGraw Hill Co., New York City.

2. Bernhard, Lynn J., P. E. Civil Engineer, 1991. U. S. Department of Interior, Bureau of Reclamation, Utah Projects Office, Provo, Utah.

3. Wildlife Society, 1969. Wildlife Management Techniques, (third edition), p. 191. Edward Brothers, Inc., Ann Arbor, Michigan.

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Over the past 12 years, the Richfield BLM District Office has developed a water impoundment referred to as the "Silt-Free Reservoir," or SFR. The SFR is designed to store water more efficiently for a longer period of time, and it has a service life two to three times that of a typical reservoir.

The document describes the construction details and costs of a typical SFR, which consists of two basins. One basin serves as a silt trap and a second basin is specifically sized and shaped to store water efficiently (i.e., minimal losses due to evaporation and underground seepage). Detailed engineering drawings are presented, along with other illustrations showing the advantages of SFR design principles.

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